AN

EXPERIMENTAL INQUIRY,

INTO

THE PRINCIPLES

OF

NUTRITION,

AND THE

DIGESTIVE PROCESS.

BY JOHN R. YOUNG,

OF MARYLAND;

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"We ought in every instance to submit our reasoning to the test of Experiment, and never to search for truth, but by the natural road of Experiment and Observation." LAVOSIER

PHILADELPHIA;

PRINTED, FOR THE AUTHOR, BY

EAKEN & MECUM.

—1803.—

AN

INAUGURAL DISSERTATION,

FOR

THE DEGREE

OF

DOCTOR OF MEDICINE;

SUBMITTED TO THE EXAMINATION

OF THE

REVEREND JOHN ANDREWS, D. D.

(PROVOST PRO TEMPORE),

THE

TRUSTEES AND MEDICAL PROFESSORS

OF THE

UNIVERSITY OF PENNSYLVANIA,

ON THE

EIGHTH DAY OF JUNE, 1803.

TO

DOCTOR SAMUEL YOUNG,

Of Hager's-Town, Maryland.

SIR,

UNDER your instruction I received my first principles in medicine, and your paternal kindness has enabled me to progress thus far in my studies: To no one, therefore, could I with so much propriety offer these, my first fruits, as to yourself. You will please then, to accept this imperfect ESSAY, as a sincere tribute of thanks, for the instruction received from you, and of filial affection, for the long guardianship, so uniformly experienced,

By your son

And pupil,

THE AUTHOR.

TO

BENJAMIN SMITH BARTON, M. D.

Professor of Materia Medica, Botany, and Natural History, in the University of Pennsylvania;

A GENTLEMAN NOT LESS DISTINGUISHED

BY

EMINENT SKILL IN HIS PROFESSION,

THAN BY HIS ZEAL,

TO PROMOTE EVERY BRANCH OF USEFUL KNOWLEDGE;

THIS ESSAY

IS ALSO INSCRIBED, AS A SMALL TRIBUTE

OF

RESPECT FOR HIS TALENTS, AND GRATITUDE

FOR THE MANY FAVOURS RECEIVED,

BY HIS FRIEND,

AND PUPIL,

THE AUTHOR.

AN EXPERIMENTAL INQUIRY,

&c. &c. &c.

MAN is endowed with motion, sensation, and thought. These are dependent on some internal or inherent principle, and also on various external agents; when they are all regularly performed, they are said to constitute perfect animal life. When we contemplate this life, we are struck with motion, as its principal characteristic; and when we take a farther view, we must perceive that this motion and its laws, must necessarily tend to waste the machine in which they reside. It becomes essential therefore to the existence of the living body of man, that he be provided with means to counteract his tendency to decay. To effect this, he is furnished with an apparatus which prepares new materials, to supply the waste of the old; and these the beneficent hand of nature has plentifully defused, over every part of the globe. Lest he should neglect them, he is furnished with faithful centinels, which seldom fail to admonish him of the exigences of the system; and as life would be endangered were those admonitions but feeble and temporary, Hunger and Thirst are among the strongest, and most impatient of all sensations, and the gratification of them is accompanied by the most exquisite pleasure.

In the present Essay it is proposed to consider these substances, which supply this waste and growth of the system, and the changes they undergo previous to their entering the circulating mass; or the Nutrientia, and their Digestion.

NUTRIENTIA.

By the nutrientia are meant, such substances, as taken into the system, are suited to supply its growth, and the waste of its solid and fluid parts. The articles taken as aliment by man, comprehend an immense variety of substances, in the animal and vegetable Kingdoms, and as we presently shall attempt to shew some from the Mineral. It has been, however, a disputed question, whether his natural food be confined to animals or vegetables, or whether he be carnivorous, or phytivorous; we shall take it for granted he is both, or an animal "ad omnia," which seems clearly evinced by his instinctive appetites, which urge him to use them promiscuously, in whatever clime he may be situated.

We shall not pretend to enumerate the variety of articles taken by man as food, but only attempt to point out, the principles on which their alimentary or nutritious property depends.

Dr. Cullen supposes that all animal matter is derived from a vegetable origin, because all animals feed directly, or entirely on vegitables, or upon other animals that do so; hence he refers the principal of nutrientia to vegetables; and that they derive this property from their Acid, Sugar, and Oil. These with some others we will examine in order.

ACID. This we are disposed to reject as one of the nutrientia. The Doctor appears to have founded his opinion on the idea, that all vegetable substances, when taken into the stomach, undergo

a fermentation, whereby an acid is evolved; and "as this entirely disappears with the progress of the aliment, without being again evident in the mass of blood," so he supposed it undoubtedly entered into the composition of the animal fluid. That an acetous fermentation takes place in the human stomach in a healthy state, we entirely reject, as will appear in what follows; and if this opinion be well founded, we obviate the principal argument favouring the idea, of an acid being nutritious. Acescent vegetables we cannot doubt as affording nourishment, but this is not to be referred to their acid, but to their sugar and oil. That the acid of vegetables is nutritious, seems most probable, from the circumstance of vegetables curing scurvy, a disease supposed to arise from a want of this kind of food; and the more so as the pure citric acid is found to expedite their operation. The pathology of this disease, however, is not as yet fully established. Its cure seems pretty well understood, but its proximate cause, and the modus operandi of medicines found useful in it, is still inveloped in darkness. Some have ascribed its proximate cause, to a putrescency of the fluids, and acids as nutrients, were supposed well adapted, to correct this vitiated state of the system. Modern physiologists, with much propriety, reject this supposed state of the fluids, as quite incompatible with the laws of the animal œconomy. What farther proves that the acid of vegetables, does not cure this disease by affording nourishment is, that the mineral acids have also been found to cure the scurvy, and that their hitherto inefficacy arose from not diluting them sufficiently, so that a large enough quantity was not taken. Whatever be the principle on which the mineral acids operate in this disease,

the same no doubt is to be ascribed to the vegetable; now the very advocates for this last being nutritious, reject the former as never entering into the composition of the animal fluid, on their own ground therefore we reject both. The most probable opinion appears to be, that accscent vegetables cure this discase, by the stimulus of the acid being accommodated to the excitability of the system, and that the sugar and oil of the vegitables afford the proper proportion of nourishment.

OIL.—This enters into almost all our aliments, and composes part of the daily food of all nations. Its universal use clearly evinces its nutritive property. Dr. Stark lived fourteen days on a diet of olive oil and flour, and found in that length of time, he gained in weight, four pounds eleven ounces and six drams. On a diet of suet and flour for the same length of time, he gained four pounds eleven ounces and two drams.

SUGAR.—Many proofs might be adduced to prove this one of the nutrientia; even our instinctive appetites when children, urge us to relish this, in preference to every other article of food. It is well known the negroes in the West-Indies, when preparing this article from the cane, live almost entirely on it, and become quite fat at this season. Many are the instances of the crews of ships subsisting on their cargoes of sugar, when their provisions have become expended. Dr. Cullen supposes sugar is not alimentary in its pure saline state, but only when combined with an oleaginous matter, but the above shews to the contrary.

As these two last articles, oil, and sugar, compose the principle of nourishment, in most of the articles we use as food, plethora and serious consequences would result from taking them in any considerable quantity, when in their pure state: But these are obviated, by the stomach kindly becoming satiated when they are taken in but a small quantity, and almost uniformly rejecting them when taken in excess. A remark made by the late Dr. Stark, was appropriated to the present point; "does not an excess in sweets give a greater shock to the system than an excess in fats? Is there any article of food so hurtful as either, when taken immoderately?"*

GUM.—Dr. Cullen supposes this alimentary, and that it derives this property from the sugar, oil, and acid, which he imagined entered into its composition. Modern chemistry, however, rejects this analysis of gum, and teaches us it contains neither of these principles; it has however an acidifiable base, but requires another agent, oxygen, to form an acid. Independent of these principles however, it is a nutritious substance. Haselquist relates in his travels, of a caravan having expended their provisions, in pas-

* This was the last remark made by this indefatigable physician, when experimenting on himself, on the effects of different kinds of diet. He was using honey and flour as his constant food, which considerably affected his alimentary canal, and system generally. His diseased state advanced, and as usual he marked down every effect. His symptoms at length became alarming, and the last remarks he was able to note down, were the above judicious questions. Alas! his own fate soon answered them, in a few days he was cut off in the midst of his experiments, and in the blossom of life.

it was when first confined, and threw out much feculent matter. Lest it should be supposed the fish lived on substances held in the water by solution, he used distilled water and impregnated it with the air of the atmosphere, and put other gold fish in the water thus treated, and kept them six months, during which time they threw out feculent matter, and thrived as before mentioned.

The common spring frog (Rana pipiens) I have kept for two months on pure water alone, during all which time they were as plump, and active as when first confined. Indeed water appears to be their principal nourishment; for though they be brought from springs in good health, and their stomachs distended with food, and be kept out of water, they generally die in less than thirty-six hours, as I have observed from very frequent trials. When I exposed them in a dry jar but one night, they frequently become quite unable to leap, and by keeping them thus confined for twenty, or twenty-four hours, their extremities become quite dry, and withered; these consequences were always however prevented, or obviated when they did occur, by putting them in water.

It may not be improper to enter more minutely into this subject, which will be of use to us when we come to speak particularly of digestion.

To shew how dependant frogs are upon water, the following experiment will serve, as the result of many performed on this subject. A frog six hours after being brought from a spring in good health weighed four drams and two

grains. It was put in a jar containing water, where it remained for twelve hours, in order that it might gain any vigour it may have lost; at this time it weighed four drams fifty grains—it was then put in a dry jar, and in twenty-eight hours was found dead, and weighed only three drams and twenty-five grains. Many thus exposed died sooner, and others again survived longer, but one or two, however, lived to the third day.

That water was taken into the systems of these animals, was evident from their great increase of weight, when put into it after being previously exhausted: But upon opening several of them after this increase I never could find any water either in the stomach or bowels; it was conjectured therefore, that the weight they gained arose from an external absorption; to ascertain this the following experiment was performed. A frog weighing five drams and forty-six grains, was confined in a dry jar for twelve hours. At this time it had lost a great deal of its plump appearance, and was scarce able to leap, and weighed, but four drams and thirty-six grains: It was now extended upon a thin piece of board, and laced firmly; in this situation it was immersed in water as high up as its fore legs, and let remain so for five hours: Not a particle of water could be taken in by the frogs mouth, as its head was above water, and firmly fixed to the board. At the expiration of this time it was dryed, and found to have gained fifty-two grains, so that it had externally absorbed this weight of water. Many experiments of a similar kind were, performed and all with the same result.

Their external absorption was ascertained in another manner; by exposing them in damp grass during the night, after being previously exhausted by keeping them from water, they always regained their original weight, or the loss they sustained by being kept dry.

Having thus ascertained that frogs are nourished by an external absorption of water, it occured that on this principle we might explain how snakes are supported many months, without eating the least particle of food. Dr. Barton has kept a rattle snake for eighteen months during all which time it never eat any thing.—And I myself kept a copper snake during the last summer, for more than three months, all which time it refused to eat, though its natural food was frequently presented to it. This occurence appeared quite inexplicable to me, how action and exercetion could go on such a length of time when no food was taken: I was led therefore to suppose it could not have abstained from food all this time, but must have occasionally have caught insects, that might have crawled or fallen into its cage; but I had no reason to have recourse to these conjectures, when I heared of the above fact accuring under so careful an observer as Dr. Barton. With a view of ascertaining whether snakes derive nourishment from an external absorption, the following experiment was performed.

A snake was kept confined in a dry jar for five days; at this time it was lean and quite inactive, and weighed one ounce four drams, and fifty eight grains. It was now extended upon a narrow board, on which it was laced firmly; in this situation its whole body, except about three

inches of its upper part, was immersed in water, where it remained for three hours.—Upon being taken out and dried, it was found to weigh, one ounce seven drams and twelve grains, so that it absorbed two drams and fourteen grains, in the short space of three hours. Hence it would appear, that frogs and snakes like plants, derive a considerable portion of their nourishment from water alone: and that snakes, when kept confined, are nourished by absorption from a moist atmosphere, as from moisture condensed on their surfaces.

How simple water can go to form an animal substance, we shall not pretend to offer a conjecture; we only state the fact, and shall leave the Hydrogen and Oxygen of the water, together with the different gasses, taken in by the lungs, to the chemist, who by variously combining them, may explain the phenomenon.

OXYGENE.—As this enters into the system and becomes fixed, thereby supplying a waste that constantly takes place; it properly comes under our definition of nutrientia. The intimate connection of life, with a constant supply of oxygen gas, is now fully esablished: It is the least to be dispensed with, of any of the nutrientia. The experiment of Dr. Priestly, who exposed a bladder containing venous blood, to an atmosphere of oxygen gas, which passed through the coats of the bladder, and turned the external surface of the blood to the arterial red, shews in a beautiful manner, how the vital air of the atmosphere, penetrates the tender membranes of the lungs, and oxides the blood.

LIGHT.—Animal as well as Vegetable life, exists but in an inferior degree, when deprived of light; that life may continue, however without it, the unhappy subjects of Tyrants, have too often witnessed: but as animals do not arrive to their full growth and vigour when deprived of light, it deserves a place here. Professor Barton mentions, his having found a hoard of young mice, in a cellar, where they had been deprived of light; they were all white and sickly. The experiments of Newton prove light to be material and divisible; but whether as matter it enters into the system, we cannot say: we are therefore doubtful whether to consider it strictly as one of the nutrientia, or whether it might not with more propriety be looked upon, in the light of a condiment.

HAVING thus considered the nutrientia, we now proceed to examine the processes these undergo, previous to their entering the circulating mass.

THE food is first masticated, and during this process is well mixed with saliva. This fluid is poured into the mouth from the parotid, submaxillary, and sublingual glands. These are excited into action by pressure, or the action of the lower jaw, by stimulating substances applied to their ducts, and by the action of the mind*,

* Is not the secretion of the Saliva and Gastric fluid synchronous? It is highly probable from long habit, the actions of these two sets of vessels become associated; hence, when the stomach and its vessels are irritated, as in nausea, there is always a flow of Saliva, though nothing stimulating has been applied to the

all these causes operate when we are eating, and the fluid thus flows in greatest abundance, when most required. By deglutition it is then conveyed into the stomach, where it meets with a second fluid; the *gastric*, which constantly flows from the coats of this viscus. It bears a great resemblance to saliva, but differs from it, and all other animal fluids, in being a powerful menstruum for animal and vegetable matter. The food after being retained in this reservoir from three to six hours, is expelled into the duodenum, in a dissolved or pultaceous mass; here it meets with two other fluids, bile and

mouth. The excitement of the vessels of the one, seems to keep pace with that of the other; when the nausea is so great that vomiting is just at hand, the flow of the saliva is proportionally increased; and when we make an unsuccessful effort to vomit, we generally throw out a mouthful of saliva. If this association of vessels be admitted, will it not explain the modus operandi of salivating medicines? All the preparations of mercury affect the stomach and its vessels, and as we suppose by association the salivary glands. When one dose of Turpith mineral is taken, it produces a temporary flow of saliva, as soon as it acts on the stomach: When, therefore, this or other preparations of mercury, operate permanently on this viscus, a permanent flow of saliva takes place. But how does it operate when externally applied? We answer by its action being always determined to the stomach; being in this respect on a footing with many other substances—Thus, Ipecacuanha affects the stomach, even when injected into the blood-vessels; and Tobacco nauseates when externally applied, and in the form of enema. Many other substances salivate, as Digitalis, Seneka, Tart. Emet. Squills, &c. and all in small quantities will puke. This theory will also explain, why children, under a certain age, cannot be salivated, because these two sets of vessels have not acted long enough together for their motions to become associated.

pancreatic liquor, and being mixed with these, a mass is formed, capable of affording chyle.

We now proceed to examine this process, in a more particular manner.

Digestion is performed in a similar manner, in all animals with membranous stomachs; they all have a general receptacle into which the food is received, and exposed to the action of a dissolving menstruum; and all have bile and pancreatic liqour with which it is afterwards mixed. As food is then exposed in all, under the same circumstances, similar effects must be produced upon them, or the process (generally speaking) is the same. We shall avail ourselves, therefore, of this similarity, and throughout, we shall not confine our observations to man alone, but also attend to that of other animals, by which we may draw plausible if not conclusive inferences concerning our own digestion. We go on to speak generally of

SOLUTION.

It would be unnecessary to recite particular experiments, to prove the solvent property of the gastric fluid, this being admitted on all hands. Under this head we shall, therefore, only make general observations, concerning the solution of various substances by different animals.

The effects of solution are most remarkable in such animals, as swallow their food without mastication, we will therefore, relate a few experiments made on some of these.

Our common large bull frog (Rana ocellata) was chosen in order to observe the effects of the gastric fluid, as they swallow all their prey whole. They have a large membranous stomach, which when distended, occupies the whole anterior part of the abdomen: the œsophagus is very wide, so that their food can be examined at pleasure. Two of a very large size were procured, and their stomachs were found to be greatly distended with food: being desirous of seeing what was their natural aliment, and the effects of their digestive power upon it, by means of a pair of forceps, one of their stomachs was easily emptied of its contents; and to my suprise, and that of others who witnessed the fact, it was found to contain a common sized spring frog; and affording a fine opportunity to see the effects of their gastric liqour. The whole external surface of the frog was acted upon, the muscles having superficially, quite lost their texture; some parts of the back bone were bare, the spinous processes of which, were quite soft. Upon introducing a forceps, a second time, the hinder parts of a second frog were found, which shewed the effects of their fluids in a still greater degree: the muscles of the thigh were reduced to a complete jelly, though still retaining their form; some parts of the bones that were covered with flesh, were quite soft and flexible. Upon extracting the contents of the stomach of the second frog, it was found to contain a field mouse, about a third larger, than our common mouse; its whole surface was quite soft, having entirely lost its texture; the fore legs were nearly disconnected from its body, the bones of which were soft, the bones of other parts of the body, were also examined; they were all soft: But

what was most surprising, the teeth of this animal did not escape; the incisores were, as Dr. Jacobs witnessed, soft and flexible, having the appearance of a piece of half dried tendon. Neither the frog nor the mouse had any acid or putrid smell.

It appeared very evident from the preceding experiment, that the fluids of these animals acted upon bones; but in order to ascertain whether they could dissolve them completely down, the following experiment was performed. The head and all the bones of the mouse were cleared of their flesh, and forced into the empty stomach of one of the frogs; he was then put into a jar of water. In two days, the bones were all discharged in the form of a mortar, by rubbing it between the fingers, small pieces of bone were distinguishable. This will serve to shew us, the powerful action of an apparently inert fluid on an animal matter, sparing not bones, nor even the teeth of animals.

Being desirous of knowing the length of time they would require to dissolve down a small frog, the following experiment was performed.—A pack thread was tied to the hind legs, of a living spring frog—Its head was then put into the mouth of one of the large frogs; as soon as he felt it move, it was swallowed greedily. In five hours it was drawn up by means of the thread, the skin and external surface of the muscles were tender. It was again introduced. In the space of seven hours, it was drawn up a second time; the abdominal muscles were now dissolved, and the intestines had protruded, the bones of the feet were soft, and separable from the leg by the least force;

in a word the whole was a complete dissolved mass. It was swallowed a third time, and attempted to be drawn up in six hours afterwards; but it had so far lost its texture, that the two legs to which the thread was tied, could only be brought up; the bones of these were soft and flexible, as before mentioned. Many experiments of this kind were made to see the effects of their gastric menstruum: In many cases, after giving them small frogs, the trunk and head of these animals were drawn out of their stomachs complete skeletons, but the bones were always soft, and felt like tender cartilage. In all the half digested substances which were at different times taken from their stomachs, as frogs, veal, beef, &c. an acid was constantly found present: they were seldom examined before two hours after being swallowed; at this short interval when their surfaces were touched with litmus paper, it was turned red.

Snakes, like the large frogs, also swallow their food without mastication; many experiments were therefore, also made on them, by forcing, frogs, lizards &c. into their stomachs, to see the effects of solution; they agreed in every respect with what has been said of frogs; like them perfectly dissolving down entire animals; the only difference between them was, that the solution of snakes, went on only about half as fast, as that of the large frogs.

The gastric fluid of man, and that of frogs and snakes, agree perfectly in their action on flesh; as the experiments of Spallanzani prove, that the first of these powerfully dissolves meat out

of the body. As the menstruum of the two latter animals acted so uniformly on bones, it appeared highly probably, the fluid of our own stomachs would also. To ascertain this, the condyles of the thigh bone of a chicken, weighing eleven grains, were swallowed; the bone remained a considerable time in the stomach, as was supposed from some uneasy sensations, that were occasionally experienced, for between two and three days, the fourth day it was discharged, reduced to a shell, weighing only three grains. Thus far the digestion of man, and these animals perfectly agree in solution, being the first step towards the conversion of food into chyle; but they differ in some particulars, and probably by attending to these, they may be of use to us.

First. They are cold blooded animals; heat is a powerful agent in all solutions, and the experiments of Spallanzani prove, it greatly assists the action of the gastric liquor, out of the stomach.

Secondly. They do not masticate their food.

These two inconveniences are obviated, by these animals never drinking when their digestion is going on, so that their fluid acts in its undiluted state; whereas in man, it is always diluted, as he seldom eats without drinking. That this was the case with these animals, I had clear proof; for although I examined the contents of their stomachs so often, in no one case could I find any fluid, more than a jelly like substance, appearing to be made up of gastric juice and dissolved flesh. Supposing however that the pressure used in bringing up the food of the frogs might have

forced the more fluid parts into the duodenum, I resolved to ascertain the fact in another way; this was easily done: A tea-spoon could readily be passed into their stomachs, and with this the dissolved food could all be brought up; it was always however of the consistance above mentioned*. During the time these experiments were made, they were constantly kept in large jars of water. The attention to this circumstance, by these animals, which swallow their prey entire, is a necessary part in their digestion; as they require a very powerful menstruum, so as to disolve not only entire muscles, but also bones. The inference we would draw from it, would be, to attend occasionally, to what necessity urges them to observe constantly. Thus when our stomachs are weak, or we are troubled with dyspeptic symptoms, like them we ought to avoid much diluting our gastric juice; so that although it were secreted not perfectly healthy, yet having the advantage of acting in its uncombined state, solution and digestion may go on; when it otherwise would not, with the common quantity of drink. Indeed our stomachs in this respect act a kind part to us; for when we make our first dish on broth, it seldom relishes much solid aliment after it: hence soups are the first dish at the table of the temperate, and the last at that of the epicure.

* The Eagle appears to observe the same rule respecting drink. Mr. Peal informs me his Eagle never drinks during the cold season; and that he only gives it water in the hot summer weather, when it is fond of washing itself in it, and will then occasionally drink, but very sparingly. It is highly probably most carnivorous animals that swallow their prey whole, or piecemeal, observe the same rule.

While speaking of the solvent property of the gastric fluid, it may not be improper to observe, it has lately been ingeniously proposed as a solvent for the stone in the bladder. In this disorder we have hitherto only had recourse to the knife: but such a formidable and dangerous operation, makes other means desirable. Dr. J. S. Dorsey has proved the gastric fluid may be introduced into the bladder with safety; no endeavours therefore ought to be lost in ascertaining what fluid may act on calculi, with most effect. From the facility with which bones and teeth were dissolved by frogs, it appeared highly probable, their fluid would also operate on calculi. On this subject the following experiment was made.

A calculus was obtained from Dr. Jacobs, of a very firm texture, weighing exactly fifty grains. It was introduced into the stomach of one of the large frogs. In two days it was taken out for examination; at first sight it was evident, solution had taken place, for the gastric juice which adhered to it, was coloured with some of the dissolved stone: It was found to weigh forty-five grains. It was forced into the stomach a second time; where it remained for two days; It now weighed thirty-eight grains; from this it appears, it is well worthy of more attention: when introduced into the bladder with the heat of the human body; we have little doubt it would act upon calculi with much effect. Their fluid is easily procured, and without the necessity as in other animals of sacrifising a life every time we wish to obtain it: by means of a tea-spoon, it is readily brought up from their stomachs.

Spallanzani and most modern naturalists take it for granted, that some carnivorous animals, particularly birds, cannot digest vegetable matter. This opinion if well founded is of importance, not only as it concerns the natural history of those animals, but also as it relates generally to the theory of digestion. There is a great analogy subsisting between man and such birds in their digestive processes: They both have membranous stomachs into which food is received, and exposed to heat and moisture; circumstances equally favourable in each to a fermentation; But if it shall appear such birds cannot digest vegetable food, which under equal circumstances ferment sooner than flesh; we are justified in concluding a fermentation has nothing to do with their digestion; and from the great analogy just mentioned, we raise a strong argument in opposition to fermentation, being the efficient cause of our own digestion.

Spallanzani and Reaumur have both attempted to support this opinion by experiments: I know well the distinguished rank both these authors hold in the philosophic world, and the weight of their authority in any opinions they may have advanced. Perhaps no man in the age in which he lived, considered subjects in a more philosophic point of view; or threw more light on such as he undertook to examine, as the former of those naturalists: his works will remain as long as experimental philosophy, holds its present footing among the learned. With due difference then to this high authority, I would beg leave to differ, or at least to raise a doubt to the opinion above stated: "Aliquando bonus dor-

mitat Homerus." Experiments are the sure and unerring guides to truth, when they alight the path we ought with confidence to persue it, though authority should oppose.

Before attempting to point out the fallacy of their opinion, we shall premise the following experiments and observations.

The large frogs so often mentioned are purely carnivorous, as I never could find any vegetable matter in their stomachs. Into the stomachs of different ones, were introduced beans, pease, wheat, and bread, inclosed in linen bags: In thirty hours they were all taken out for examination; the pease, wheat, and beans were entire, and not the least acted upon; but the bag that contained the bread was quite empty. This experiment confirmed to me, a conjecture formed by looking over the experiments of those two naturalists mentioned above. Does not the *living principle* in seeds resist the digestive powers? But this will be answered better presently.

Bags containing beans, pease, and wheat were again introduced into the stomachs of frogs, in which they remained for three days: Upon being examined at this interval; they were all found swelled, but quite entire. Bags containing beans and pease well bruised and bread, were then forced into the stomachs of these frogs; were they remained two days—upon examination they were all found empty. Life or a susceptibility of life certainly exist in seeds; and is in some inexplicable manner connected with organization. Seeds as above stated when their

texture was not destroyed, uniformly resisted digestion; but on the contrary, when their organization was destroyed, they were as uniformly digested: Hence we think ourselves justifiable in concluding the gastric fluid cannot act upon seeds as long as they remain entire, or that their living principle resists digestion.

It occurred, if entire seeds resist digestion; would they not vegetate if retained a sufficient length of time in the stomach? This was easily put to trial. Two beans were enclosed in a bag, and into a second, was put wheat: these two bags were then forced into the stomachs of different frogs. In six days they were examined: the wheat and beans were swelled and soft. They were again forced down, enclosed as before. In six days more, they were drawn up for examination. The tender germs had now protruded in both the wheat and beans, as was quite evident, and witnessed by Dr. Barton and many others.

From the above experiments we will be able to give credit, to a case related by the great Italian anatomist Morgani. He informs us that a young lady living entirely on vegetables, (it being lent) was seized with a violent affection of her stomach, and great emaciation ensued. Different medicines were used, but without the least aleviation of her symptoms. At length a violent vomitting commenced, and to the astonishment of all present, she threw up a small plant, with perfect leaves and roots! This at first sight might be looked upon as approaching the marvellous; yet why should we doubt it?—The authority of our author is as respectable as any other of our profession; and we have just seen that seeds will

vegetate when retained a sufficient length of time in the stomach. The probability here was, that the young lady had swallowed the seed of some small plant, without destroying its texture by mastication ; which being retained in the stomach, and exposed to heat and moisture, vegetation progressed.

Having thus, we hope, established one point, that seeds resist the digestive powers unless their organization or vital principle be previously destroyed ; we are now prepared to examine the experiments of those authors beforementioned, which seem to prove, some animals cannot digest vegetables.

The following are the experiments M. de Reaumur founded his opinion upon, that some carnivorous birds could not digest vegetables. To a kite he gave beans enclosed in tubes, which were retained in the stomach of the bird for a considerable length of time : upon the tubes being thrown up, the beans contained in them, were not the least affected by their gastric fluid, tho' it had free access to them. Pease and wheat were tried in the same manner, and with a similar result. These experiments appeared to our author, satisfactory ; but his erroneous conclusions from them, will be apparent, from what has already been said : had he bruised his seeds, we have little doubt he would constantly have found his tubes empty, when thrown up by these birds.

Spallanzani gave great weight to Reaumur's opinion from the number of the experiments, and variety of animals on which he performed them : we shall candidly examine all he advances in

support of his principle. After making some remarks on the subject, he observes, " I had proof of this opinion being true, from what occurred to my owls: They would swallow a whole sparrow, and thus receive into their stomachs, the feathers and undigested food those little birds contained in their crops. After the flesh had been digested, the feathers were vomited in the form of a hard ball; and along with the feathers, the grain; which though softened by maceration, yet continued whole: And when the small birds had eaten bread, if the matted feathers be disentangled, we may *generally* perceive traces of bread." The seeds here thrown up are no proof of his doctrine; neither is the bread, if we attend particularly to what he himself tells us. " Traces of bread were" only " generally to be perceived:" We have little doubt our Naturalist, by attention, would just as generally perceived traces of flesh; for to me it is impossible to conceive how feathers contained in the stomach, could be matted into a ball, without some of its contents being entangled and matted with them, and of course traces of bread and flesh to be perceived when the ball was opened.

His second experiment is, in all respects similar, and equally as exceptionable as Reaumer's: consisting in forcing tubes containing entire beans and pease into the stomachs of different owls; the result our reader will anticipate; none were dissolved.

His third experiment was on the falcon: he inclosed pease, portions of apples and pears in tubes, which were forced into the stomach of his bird; though retained for a length of time

they were all discharged, and none of their contents dissolved : the pease we pass over ; but the apples and pears were not acted upon. Does not this prove the falcon could not digest, at least, some vegetables? We believe not ; and would explain this on the same ground, we have all the rest. We do not understand the nature of life ; but we may lay it down that every substance of the vegetable and animal kingdoms, which under certain circumstances, resists a spontaneous dissolution or fermentation, has life. Apples and pears are regularly organized, have vessels, juices, &c. and for a time resist dissolution, and therefore have life ; and consequently cannot be dissolved by the gastric fluid until their texture be completely destroyed.

Spallanzani anxious to extend this principle, next had recourse to the eagle ; but unfortunately for his doctrine, he first tried it with bread : when he gave it to the amount of six ounces of this at a time, it was not thrown up as indigestible substances were, nor did it appear in the excrements ; he was therefore " obliged to conclude this species of vegetable was digested." He next gave this bird seeds of cerealea and wheat ; but these were not altered ! At this he expresses his astonishment (at the same time tacitly informing us our doctrine is true) by observing, " It is somewhat surprizing that this should be the case with wheat, when wheaten bread is so perfectly digested."

We have only one more objection to obviate ; which is in one or two experiments, boiled seeds were tried with some of these carnivorous birds, yet were not digested : In answer to this

state, the following quotation from Dr. Barton's *Elements of Botany*. When speaking of how extremely tenacious seeds are of the vital principle, our author observes : " Thus the late illustrious Spallanzani discovered there are certain kinds of seeds which do not refuse to vegetate, even after having undergone the operation of boiling in water, and Duhamel mentions an instance of seeds germinating, after they had experienced in a stove a heat of 235 degrees of Farenheit. Spallanzani even found that the seed of mould, which is a true vegetable, survive a heat infinitely greater than this."

We have thus examined this subject at large, which, from its importance, it seemed to demand. As yet we think there is no proof, but that all animals can digest vegetables, and, by habit, may be brought to live upon them : dint of hunger will learn, and habit will soon confirm these wide transitions ; so, that animals naturally carnivorous, will subsist on vegetables ; and graminevorous on flesh. In proof of these assertions we state the following. Dr. Barton informs me, he has received information from a respectable gentleman, Mr. Watkins, stating, that he has seen two Polar Bears *(Ursus Arctos)*, that had subsisted an vegitable food alone, from the time they were taken from their mothers breasts ; and that they were more than half grown, and very fat. These animals in their natural state, are as purely carnivorous as the lion. Spallanzani acknowledges his eagle could digest bread ; and Buffon informs us " when they are unable to procure flesh, they feed on bread." The large bull-frogs purely carnivorous, digested, and were supported by bread. On the

contrary graminivorous will subsist on flesh. The Italian naturalist so often mentioned, by dint of hunger learnt a pigeon to eat meat, of which it became so excessively fond, that it preferred it to every other kind of food, even to wheat, which in their natural state, they eat before every thing else.

With this we dismiss our observations under the head of solution: and shall now proceed to examine how aliment is converted into chyle.

We have already seen the powerful action of the gastric fluid, by which the food is completely dissolved. But will simple solution explain the conversion of aliment into chyle; a fluid differing from it in so many particulars; and yet always the same, whatever be the nature of the food? The most natural explanation of this phenomenon, would be by a fermentation, by which we know bodies are entirely altered in their nature. This opinion bears the face of probability, inasmuch as the food is detained in a warm reservoir, and exposed to moisture, circumstances highly favouring this process. On this account, and from the respectability of those who have stood in its defence, as Pringle, Macbride, Cullen, Dr. Rush, &c. it deserves our particular attention. We therefore, proceed to examine the doctrine of

FERMENTATION.

Chemists divide fermentation into three kinds; the vinous, acetous, and putrefactive; the product of the first is vinous spirit, or alcohol,

of the second acetous acid, or vinegar, of the third ammoniac or voletele alkali.

In order to ascertain whether a vinous fermentation could take place in the human stomach; the following experiment was performed. My friend Mr. Mitchell avoided his usual breakfast, in the place of which he took, between the hours of eight and ten, twelve ounces of sugar. Nothing more was taken until one o'clock. Having the power to ruminate, it was at this hour thrown up.—the mass was sweet: upon being put to rest, no intestine motion, or disengagement of air was to be perceived. It was then submitted to distillation: A limpid fluid passed over into the receiver, which was sweetish, but had none of the properties of a vinous spirit. Carbonic acid gas is constantly evolved during the vinous fermentation; Mr. Mitchell, therefore paid particular attention to this, as long as the sugar was on his stomach; but their was not the least eructation of air during the whole period the experiment was going on. If ever a vinous fermentation took place in the stomach, we expected to have found it in this experiment; as this viscus was plentifully supplied with saccharine matter, which passes so readily to this state: but as nothing of the kind occurred, we conclude the vinous fermentation has nothing to do with the digestive process.

We next speak of the acetous fermentation.

The arguments advanced in support of the opinion are, 1st. Heat and moisture of the stomach. 2dly. The disengagement of air from this viscus. 3ly. The fluids with which the food is

mixed, quickly running to the acetous fermentation. 4ly. The presence of an acid in the stomach. These we will examine in order.

To the first argument we give its full weight, being founded in truth. But to the second, the disengagement of air from the stomach, we object to, as giving any support to this doctrine. This is constantly spoken of as a uniform occurrence; whereas every one who has attended to the state of their own stomachs, must confess, they have frequently digested meals, without the eructation of a particle of air: With much propriety therefore, we might reverse this argument, and bring it as a strong objection to this doctrine.

3dly. The fluids with which food is mixed quickly running into the acetous fermentation. The saliva is said quickly to pass into this process, as the experiments of Macbride and Dr. Rush clearly prove. Those gentlemen mixed some vegetable and animal matter with saliva, and others with water. Upon placing these under equal circumstances, in a moderate heat, the vegetable and animal matter mixed with saliva fermented much the soonest. From this they draw a strong argument, apparently favouring the same taking place in the human stomach, the food there being plentifully supplied with this fermenting juice. Aliment is not however, in these experiments, exposed under all the circumstances it is when in the stomach; a fluid of much more importance than the one just mentioned is left out, and of course the inferences drawn from them cannot be valid. The gastric juice Spallanzani found, powerfully to resist fermentation; and

even restored putrid substances to their original sweetness, as I have also witnessed with my frogs. In the following experiment however, food is exposed under all the circumstances it is when in the stomach, but with a different result from those just mentioned. On an empty stomach I made a light dinner, on chicken pye, and drank simple water: In half an hour, by irritating my fauces, it was thrown up; at this time it was plentifully supplied with gastric fluid, as well as saliva, as the quantity of food was but small. It was then exposed in a tumbler, to a heat equal to the human temperature. For the space of nine hours, there was not the least intestine motion, or any disengagement of air. As digestion is performed sooner than this period, it was not attended to any longer. From this experiment we are forced to draw conclusions, directly in opposition to those above mentioned.

4thly. The basis of this doctrine is the presence of an acid in the stomach: that this is the case we are fully convinced. But from what has already been said, it appeared to us, an acetous fermentation did not take place in the human stomach. We were therefore, lead at first to suppose, the acid was only present when this viscus was in a morbid state; but experiments proved to us the contrary: In all the different animals we examined, an acid was almost constantly found present. Hunter observes, "that in all the animals, whether carnivorous or not, which he examined, he always found an acid present in their stomachs, though not a strong one." It was before observed, that when small frogs, were digested in the stomachs of larger

ones, the dissolved mass was always acid; here "nature was interrupted in her regular operations," nothing morbid could therefore be said to be present.

The following experiments satisfied us to what this acid was to be referred. A piece of fresh veal was introduced into the empty stomach of one of the large frogs—In two hours it was examined—the surface was a little tender; upon being touched with litmus paper, it was turned red. Here digestion was progressing quite regular, yet an acid was present. It appeared impossible at the same time to conceive, the meat could become sour, in so very short a time, and in so very low a temperature; it was therefore conjectured, the acid was to be referred not to the meat, but to the gastric juice; which the following experiments confirmed us in. A frog was kept starving for two days: a piece of litmus paper was then forced into its empty stomach, by means of a pair of forceps; upon being drawn out, it was covered with gastric juice, and the litmus turned red. The naked gastric juice was afterwards, often examined, by bringing it out of their stomachs with a tea spoon, and constantly found to be slightly acid. Being thus fully persuaded the acid, in the digested food of frogs, did not arise from a fermentation, but was to be referred to their gastric juice, we were lead by analogy to suppose, the acid of our own stomachs was to be attributed to the same origin. But this analogical reasoning might be called mere probability: the following experiment was therefore performed. Early in the morning my stomach being empty, I irritated my fauces, with a view of throwing up some gastric juice: though

many efforts were made, none could be vomited. The following day, I took some meat on an empty stomach : in half an hour afterwards, by irritating my fauces, the meat was thrown up, and with it some gastric fluid: Upon being tested, an acid was very evidently present. Here no one can suppose the acid was to be referred to the meat. We have little hesitation, therefore, in saying, that the acid so constantly found in the stomach of man, and almost (probably) all animals, is to be referred to their gastric fluid.

Having thus, we hope, traced the acid of the stomach to its proper origin, we next attempted to ascertain its nature by chemical tests. Mr. Mitchell being in good health, and having the power to ruminate, frequently threw up the contents of his stomach for me; which being filtered a transparent and acid fluid was obtained: on this fluid the following experiments were performed.

I. To a portion of this fluid, acetate of lead was added, a white precipitation immediately took place: this being washed, muriatic acid was added, which decomposed it, a very white powder remaining at the bottom, and a fluid above.

Comparative precipitations of urine and this fluid, by the above agents, were in every respect the same. The explanation* of urine treated in this manner is, that the phosphoric acid of this fluid, decomposes the acetate of lead, forming an insoluble phosphate of lead ; this being washed, by the addition of muriatic acid it is decomposed, Plumbum cornuum or a muriate of lead

* See Lavosier.

formed, while the phosphoric acid remains in a liquid state above, which by disoxygenation affords phosphorus.

Though great accuracy, and many varied experiments are required to ascertain certainly, the presence of an unknown acid, yet we are disposed to believe any person who had witnessed the great similarity in the comparative precipitations just mentioned, would have pronounced the same explanation was to be applied to both, or that the acid in the filtered fluid was the phosphoric.

II. To a solution of silver in the nitric acid, some of the acid fluid was added, a precipitation immediately ensued.

III. Mercury was precipitated by it from its nitric solution.

IV. Lime was precipitated from lime water.

Authors inform us, the phosphoric acid precipitates all these compounds as above mentioned, forming phosphates. Experiment the first proves, the acid of our fluid is not the acetous, as it precipitated lead from the acetous acid.

From the acid in the stomach being the the phosphoric, we explain why some metallic substances, are so uniformly acted upon, when taken in the stomach. The Italian physicians recommend iron in its pure metallic state as a tonic; and experience has confirmed* its efficacy:

* Does not the uniform effects of iron in its metallic state, prove that an acid is always present in the stomach?

here the iron is acted upon by the phosphoric acid.* Copper is also dissolved in the stomach and by the same agent. In the acidity of dysptics and pregnant women, where the quantity of acid in the gastric fluid, is morbid in quantity, similar to what the lithic is sometimes in affections of the kidneys; we learn the superiority of lime water as a corrector, from its great affinity to phosphoric acid.

We shall conclude on this subject with one more observation. We have already seen lime is one of the nutrientia; no one supposes this can undergo a fermentation: we all agree as to the simplicity and uniformity of nature in all her operations; but, according to the above doctrine, it would be departing widely from this, to say, she does not ferment all the nutrientia, previously to their entering the circulating mass. Water we have also seen above promotes the growth of animals; here she would be again forsaking her accustomed path; for none of her laws teach us pure water will ferment, in the short time necessary for digestion to be performed.

Having thus rejected fermentation, we proceed to attempt the explanation of the digestive process on other principles.

We have already seen the food is completely dissolved by the gastric fluid, and then mixed with two other fluids, bile and pancreatic liquor. But as was before observed, will simple solution and mixture explain the conversion of aliment,

* Dr. Barton's MS. Lectures.

into a fluid having none of the properties of either ? Or will it explain how two different articles as bread and meat, are changed to the same substance ?* I confess I cannot conceive it will. Thus, if " vitriolic acid be added to iron, Ferrum Vitriolatum is formed." But if " vitriolic acid be added to a different substance as copper, it will not form the same Ferrum Vitriolatum, but a substance quite different, the Cuprum Vitriolatum." Solution and mixture will not then explain the true digestive process, or how food is converted into chyle.

In attempting to account for this, we shall begin by observing, chyle does not exist ready formed in the alimentary canal, any more than bile exists in the blood-vessels ; for, by no process can we obtain either from them. The formation of these two fluids therefore, we look upon in the same point of view. They are both formed by two secretory processes. The alimentary canal we look upon, as a Vena Portarum, or a Vena Intestinalis, which circulates its dissolved and heterogeneous mass ; like to the portarum, it has secreting ducts, or lacteals leading from it ; and like to it a reservoir or thoracic duct, into which it pours its secerned fluid. We would therefore explain this process in a few words. Aliment is dissolved by the gastric menstruum ; it then passes into the duodenum and meets with bile and pancreatic liquor ; after being united with these, a heterogeneous mass is formed called chyme, and from this the lacteals secrete chyle.

* Dr. Fordyce fed two dogs, the one on meat, the other on bread. Upon killing them, the chyle of both were found to agree in every respect.

We are lead to believe this to be the true doctrine, because as before observed, simple solution will not explain the phenomenon of digestion. Nor will the mixture of this dissolved mass, with bile and pancreatic liquour, change it into chyle; for we know chyle is formed when both these fluids are wanting: thus nutrition goes on when the biliary duets are obstructed, and also when the pancreas is schirrous. That the absorbents have a secreting or digestive power, we learn from the following. Dr. Wistar informs us of a remarkable case, which occured under his own observation, of a person who was supported for many weeks, by nourishing enemata, alone. Here it cannot be said there was bile, gastric and pancreatic liquors to assimilate the injected fluid into chyle: yet chyle was formed and the system nourished. If the lacteals acted the part of simple absorbing, or capillary tubes, their contained fluids ought to partake of the sensible properties of the mass from which they are absorbed. But the reverse of this is the case: chyle has always the same taste, however different the sensible properties of the contents of the intestines may be, whether they are acid, bitter, &c. We draw a strong argument in truth of this opinion, by turning to the vegetable kingdom; throughout the whole of which, the digestive process is seated in the absorbents. Water is to them, what the fluids of the prima via are to the digestion of man: it dissolves their food, which being exposed to their vessels is taken up: but the fluid thus taken up, cannot be imitated by any mixture of earth and water; any more than we can imitate chyle, by combining aliments with the fluids of the alimentary canal. As we thus have proofs, the one

is a secretory process ; why not admit that of the other, to be so also, since the circumstances of each so perfectly agree.

THERE is as yet one point remaining, which it is necessary for us to notice.—The powerful action of the gastric fluid has been frequently mentioned in the preceding pages, as dissolving animal and vegetable matter : If animal substances are so readily dissolved by it, why does not this fluid also dissolve the stomach ?

HUNTER in the course of his dissections, frequently observed the large curvature of the stomach to be dissolved, particularly in such subjects as were carried off by sudden death : This dissolution he ascribes to the agency of the gastric fluid, but in the living body he supposed, the vital principle of the stomach effectually resisted its action. This ingenious explanation has been objected to, the solution mentioned is said to arise from a putrefaction, that the same takes place in the intestines, where no such solvent fluid is to be found : Spallanzani though he appears to accede in great measure to Hunter's idea, yet he observes ; " Too much is attributed to this principle". He supposes whatever possesses life is capable of resisting the action of the gastric fluid ; his arguments by no means prove this. The following considerations will render the general proposition doubtful. Fish dissolve and digest living crabs, lobsters, &c. The leech is concocted by the human stomach, though it has no pores, and can sustain a temperature equal to that of man."

As the large frogs swallow animals alive, it was supposed they would answer very well to investigate this prineiple. As it was observed of the fish above, these large frogs without doubt swollowed living animals, and very soon digested them. But does the gastric fluid aet upon them before death? The following experiment proved to uselearly it did not.

A packthread was tied to the leg of a living frog; it was then given to one of the large frogs, who immediately swollowed it. In five minutes it was drawn up, and as soon as it was extrieated from the mouth of the large frog, it leaped away. It was swollowed a second time, and remained in the stomach for eight minutes, when it was drawn out—it was still alive, though quite unable to leap. It being swallowed a third time, it was examined in fifteen minutes afterwards, when it was dead. Upon opening the mouth of the large frog when it eontained the lesser one in its stomach, the manner in which their prey was destroyed, was easily explained; the passage of the œsophagus, though it ean be greatly enlarged, yet it is eompletely elosed by doublings of its substanee; and thus effectually prevents any accession of air into their stomaehs: their prey is therefore soon destroyed for want of air.....The following experiments, we however hope, decisively prove that the living prineiple does effectually resist the action of the gastrie fluid.

Two threads were tied around the fore legs of a live, and eommon sized spring frog; its whole body, exeept the head and fore legs was introduced into the stomach of one of the large frogs: the fore legs of the lesser were made to clasp around the lower jaw of the larger frog,

and firmly tied in this situation, each of the threads were then tied to the fore legs of the larger frog also : thus situated it was impossible the small frog could be entirely swallowed down, or thrown out of the stomach of the larger one. They were then put in a bason containing a little water, where they remained undisturbed for one day and a half. The small frog upon being drawn out was perfectly alive, and its whole body covered with gastric juice, and not the least dissolved in any part. The same frog was then killed, and again introduced into the stomach of the large one in the very same situation as just described. In five hours it was drawn out, when its whole surface was completely dissolved. Having this clear proof of the living principle, resisting the action of the gastric fluid, it was next proposed to try whether the action of this fluid would be resisted by a part in which the living principle was weakened—The great sciatic nerve of a living frog was therefore divided, and introduced into the stomach of a large one as above—it was drawn out in twelve hours, when it was still alive, and the paralized extremity was quite sound.

THE END.